Robotically assisted division of a vascular ring in children

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Over the past decade, technical advances, including the evolution of thoracoscopic instruments and high-resolution cameras, have contributed to the widespread use of video-assisted thoracoscopic techniques in the pediatric population. Introduction of robotic surgical systems represents a further step in the evolution of endoscopic instrumentation. These computer-enhanced systems offer 3-dimensional visualization and significantly improved instrumentation, with motion scaling and a wrist mechanism that allow the performance of fine microsurgical tasks by using an endoscopic approach. These specific advantages make the use of this technology potentially beneficial for the treatment of pediatric patients. This report describes the use of a robotic surgical system for the division of a vascular ring in 2 patients.

Clinical Summary

The first patient was a 10-year-old girl (height, 150 cm; weight, 48 kg) who presented with the complaint of recurrent vomiting; a barium swallow showed evidence of esophageal compression. The second patient was an 8-year-old girl (height, 120 cm; weights 27 kg) who presented with a history of recurrent upper respiratory tract infections and dysphagia. Chest magnetic resonance imaging in both patients confirmed the presence of a vascular ring comprised of a right-sided aortic arch, an aberrant left subclavian artery, and compression of the trachea and esophagus consistent with a left-sided ligamentum arteriosum. Institutional informed consent for robotically assisted vascular ring division was obtained for both patients.

After achievement of general anesthesia with single lung ventilation, both patients were positioned in an exaggerated right lateral decubitus position (15°-20° slightly prone) to allow easier retraction of the left lung and better visualization of the surgical field. Routine monitoring included transcutaneous oxygen saturation, continuous end-tidal carbon dioxide, and serial blood gas measurements.

The robotic surgical cart (da Vinci; Intuitive Surgical, Inc, Sunnyvale, Calif) was positioned at the cranial end of the operating table angled 30° to the patient's left side (Figure 1). Three thoracoscopic trocars were placed in the left hemithorax to accommodate the camera and 2 robotic manipulators (Figure 1, *inset*). An additional small utility incision was placed between the left instrument and camera incisions for insertion of a lung retractor. After thoracoscopic verification of the anatomy, the camera was attached to the robotic cart, and the robotic instruments were placed through the left and right trocars.

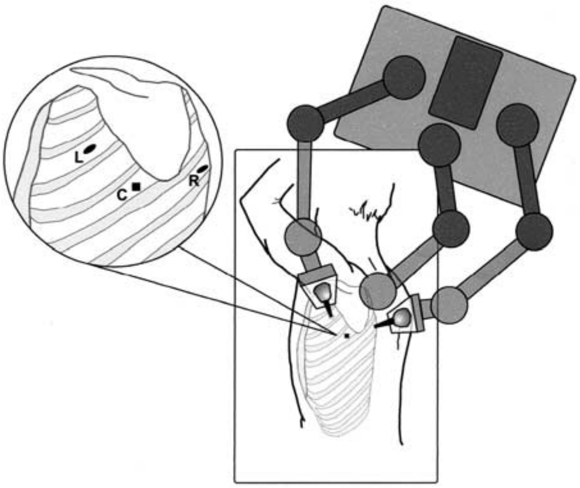

Figure 1. Intraoperative setup for robot-assisted vascular ring division. The patient is positioned in an exaggerated right lateral decubitus position, with the left arm extended above the head. The robotic arms are brought in over the patient's shoulder to allow optimal access to the upper thorax. The *inset* shows the port sites used for the cases reported here. The left instrument port *(L)* is placed in the third interspace along the anterior axillary line, whereas the camera port *(C)* is placed in the fifth intercostal space and the right instrument port in the posterior sixth intercostal space behind the scapula.

The dissection was performed with the surgeon at the master console, which was remote from the operating table, and using a grasper in the left robotic arm and a hook-tip cautery at a low setting in the right robotic arm. Once the dissection of the ligamentum was completed, 2 clips were placed at each end of this structure by using a thoracoscopic clip applier (Figure 2, *A*). Division of the ligamentum and complete dissection of the fibrous bands along the esophagus were performed with robotic scissors (Figure 2, *B*). Finally, the left recurrent nerve was identified by using an intrathoracic stimulating probe with electromyographic monitoring.[1] A single chest tube was placed through the utility thoracostomy at the completion of the procedure. Operative times were 180 and 165 minutes, respectively, with procedure times of 115 and 98 minutes. Both patients were extubated in the operating

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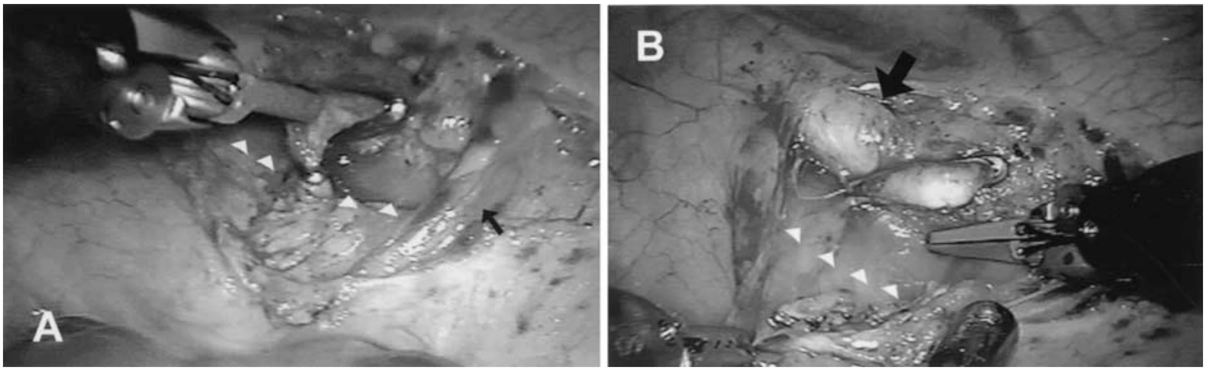

Figure 2. Intraoperative thoracoscopic views of a robot-assisted vascular ring division. The ligamentum was exposed just above the first intercostal vein *(small arrow)*. Dissection around this structure freed it from the esophagus *(arrowheads)*, and endoscopic clips were applied proximally and distally (A). Dividing the ligamentum adjacent to its origin from the diverticulum of the aberrant left subclavian artery *(large arrow)* relieved the esophageal compression (B).

room. The postoperative recovery was uneventful in both patients, who were discharged to home on the first postoperative day.

Discussion

Surgical treatment of patients with a vascular ring has evolved from the standard approach through posterolateral thoracotomy to a closed-chest video-assisted thoracoscopic approach.[2-4] This article documents the first reported use of a telerobotic surgical system for the division of vascular rings in children.

Robotic surgical systems offer significant advantages over the standard thoracoscopic approach because of improved visualization and computer-enhanced instrumentation. An important practical aspect of the successful use of robotic systems is appropriate patient positioning with proper placement of the thoracostomy incisions and the robotic arms. We have found that an exaggerated right lateral decubitus position with slight pronation of the patient allows the left lung to be positioned more anteriorly, affording better exposure of posterior mediastinal structures. Angulation of the surgical cart to the left side at the cranial end of the operating table permits optimal camera and instrument positioning.

Another important technical aspect of the operation for vascular ring division is division of all fibrous bands around the trachea and esophagus. This task was easily accomplished with EndoWrist instruments, including an articulated grasper, a hook-tip cautery on a low energy setting, and articulated scissors. Enhanced intracorporeal dexterity, optimized hand-eye alignment, and tremor filtering made tissue handling and dissection easy and accurate. The total operative time was somewhat longer than is usually required for conventional thoracoscopic division of a vascular ring, with positioning of the surgical cart and placement of the robotic arms accounting for the majority of the time difference. The dissection time, however, was slightly shorter.

Although instrument size has limited the use of robotic systems in the pediatric population, application of this technology for the treatment of patent ductus arteriosus has proved to be a safe alternative in children.[5] Furthermore, this report illustrates the utility of these systems for performing a precise dissection for vascular ring division in pediatric patients. Future advances, including decreased instrument size, use of imaging for procedure guidance, and incorporation of tactile feedback,[6] promise to further expand the applications for robotic technology in the treatment of patients with congenital heart disease.

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